November 23, 2009

MEMORANDUM TO: AFPB File

FROM: Alexander R. Klein, Chief ***/RA/***
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Division of Risk Assessment
Office of Nuclear Reactor Regulation

SUBJECT: CLOSURE OF NATIONAL FIRE PROTECTION ASSOCIATION 805 FREQUENTLY ASKED QUESTION 08-0046 INCIPIENT FIRE DETECTION SYSTEMS

The purpose of this memorandum is to close National Fire Protection Association (NFPA) Standard 805 Frequently Asked Question (FAQ) 08-0046. The enclosed position was previously sent for comment under the joint U. S. Nuclear Regulatory Commission's (NRC) Office of Nuclear Regulatory Research (RES) / Electric Power Research Institute Memorandum of Understanding process. It was later sent to the Nuclear Energy Institute's NFPA 805 Task Force for industry and other stakeholder comment. The comments that were received are available in Agencywide Documents Access and Management System (ADAMS) at accession numbers ML091970034 and ML092120077. The NRC's Office of Nuclear Reactor Regulation's (NRR) resolution of the comments is documented in ADAMS at accession number ML093220197. The enclosed position represents a joint resolution of this FAQ between RES and NRR.

Enclosure:
As Stated

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ADAMS Accession No.: ML093220426 *via email

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FAQ 08-0046: Incipient Fire Detection Systems

Guidance for Modeling Non-Suppression Probability When an Incipient Fire Detection System is Installed to Monitor Electrical Cabinets

Purpose:

The purpose of this interim position is to provide the current staff position for determining the probability of non-suppression in fire areas that have installed incipient fire detection systems.

Background:

FAQ 08-0046 was proposed by the Nuclear Energy Institute (NEI), through its National Fire Protection Association (NFPA) 805 Task Force, to seek additional guidance on modeling the use of incipient fire detection systems in Fire probabilistic risk assessment (PRA) applications. The authors believed that insufficient guidance existed on modeling these systems in NUREG/CR-6850 (EPRI 1011989), "EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities." Initial development of the additional guidance was performed under the Memorandum of Understanding (MOU) between the Electric Power Research Institute (EPRI) and Office of Nuclear Regulatory Research (RES). These efforts were not concluded prior to EPRI publication of EPRI 1016735, "Fire PRA Methods Enhancements: Additions, Clarifications, and Refinements to EPRI 1011989," in December 2008.

Incipient Fire Detection Systems have been used extensively in the telecommunications industry to minimize fire damage and limit interruption of service. A national consensus standard has been developed, NFPA 76, "Fire Protection of Telecommunications Facilities" to address fire events in these high value facilities. NFPA 76 classifies incipient fire detection systems as Very Early Warning Fire Detection Systems (VEWFDS): Systems that detect low-energy fires before the fire conditions threaten telecommunications service.

In telecommunications service, VEWFDS have proven to be very effective in detecting fires in the incipient stage that originated in electrical and electronic cabinets and low voltage electrical circuits (cable runs, junction boxes, termination cabinets, etc). In fact, NFPA 76 essentially requires VEWFDS use in high value areas such as Main Distribution Frame Equipment and other signal processing areas.

In order to achieve closure of this FAQ in a timely manner, the NRC has developed an interim position, as discussed below. This position was developed based on the staff's understanding of the VEWFDS detection equipment as well as how electrical and electronic equipment in nuclear power plants fail and should not be seen as prejudicing the NRC's view of future developments in this area. Final endorsement of this position will be addressed through the next revision of either Regulatory Guide 1.205 or NUREG/CR-6850.

Applicability

This interim position applies to Aspirating Smoke Detectors (ASD) installed as Very Early Warning Fire Detectors as defined by NFPA 76, (2009 version) installed to monitor incipient degradation in electrical cabinets as discussed below. The position is based on the information on ASD VEWFDS available to the NRC staff. NFPA 76 requires that in order for a fire detection system to be considered a VEWFDS, it must meet two sensitivity criteria: It must be set up to provide Alert thresholds of at least 0.2 percent per foot obscuration (effective sensitivity at each

port) and Alarm thresholds of at least 1 percent per foot of obscuration (effective sensitivity at each port). Licensees are free to propose the use of other technologies that meet these sensitivity requirements, but additional information/justification will be required.

Spot type detectors installed to meet the requirements of NFPA 72 may have been described as being capable of detecting fires in the incipient stage. In many cases the description of fire detection systems in licensee's design and licensing basis documentation claims that the detection system can detect fires in the incipient stage. While this my be true to some extent, in order to obtain the credit described in this interim position, the detection system must be capable of meeting the more stringent requirements described in NFPA 76.

Discussion:

The current state of the art with respect to fire detection systems includes very highly sensitive detection systems designed to sense very slowly progressing degradation of electrical components before the flaming stage of fire occurs (incipient stage). There are numerous types of electrical components that exhibit this type of failure mode, many of which are used extensively in commercial nuclear power plants. Most low voltage (~250 volts or less) electric and electronic components will degrade over a long period of time, with observable telltales that can be sensed by these sensitive detection systems.

Examples of these include terminal strips, cables, inter-panel wiring, electro-mechanical relays, transformers, switches, power supplies, amplifiers, bistables, controllers, manual-automatic control stations, indicators, gauges, and computers. In fact, a very high percentage of the electrical and electronic components inside cabinets in nuclear plants would be expected to exhibit this type of degradation.

Industry Proposal:

EPRI has developed a methodology to credit VEWFDS in Fire PRA quantification. EPRI Technical Report 1016735, "Fire PRA Methods Enhancements, Additions, Clarifications and Refinements to 1011989" includes a discussion on crediting VEWFDS in Chapter 3, "Crediting Incipient Fire Detection Systems in FPRA Quantification." There is also information on incipient fire detection systems in Appendix C, "Supplement for Crediting Incipient fire Detection in FPRA Quantification."

The EPRI report provides a good general overview of the concept of VEWFDS fire detection, as well as a good description of the types of fires that exhibit gradual degradation that is detectable using VEWFDS.

The EPRI report proposes to apply this methodology to all electrical/electronic components with a voltage of equal to or less than 250VDC or 480VAC.

The EPRI report also proposes to apply this methodology to various rotating equipment categories. Due to the variety of failure mechanisms related to mechanical/rotating equipment, the staff does not feel that application of the full risk reduction factors being considered for VEWFDS are appropriate for these components. Licensees that wish to credit risk reduction (beyond defense-in-depth) for VEWFDS that monitor rotating equipment must provide justification in the NFPA 805 License Amendment Request. The staff will consider each on a case-by-case basis.

The EPRI approach utilizes an event tree to model the factors that could impact the effectiveness of the VEWFDS in preventing/mitigating a postulated event. The event tree provided by EPRI includes split fractions for: 1) the percentage of components that would be covered by VEWFDS, 2) the reliability/availability of the VEWFDS and 3) the percentage of time the pre-emptive actions of the first responders are successful.

The NRC staff has reviewed the EPRI approach and the NRC interim staff position represents changes to that approach.

NRC Interim Staff Position:

While the approach proposed by EPRI in 1016735 provides a high level approach to modeling a VEWFDS, there are several other issues that should be addressed and conditions applied to improve accuracy/realism.

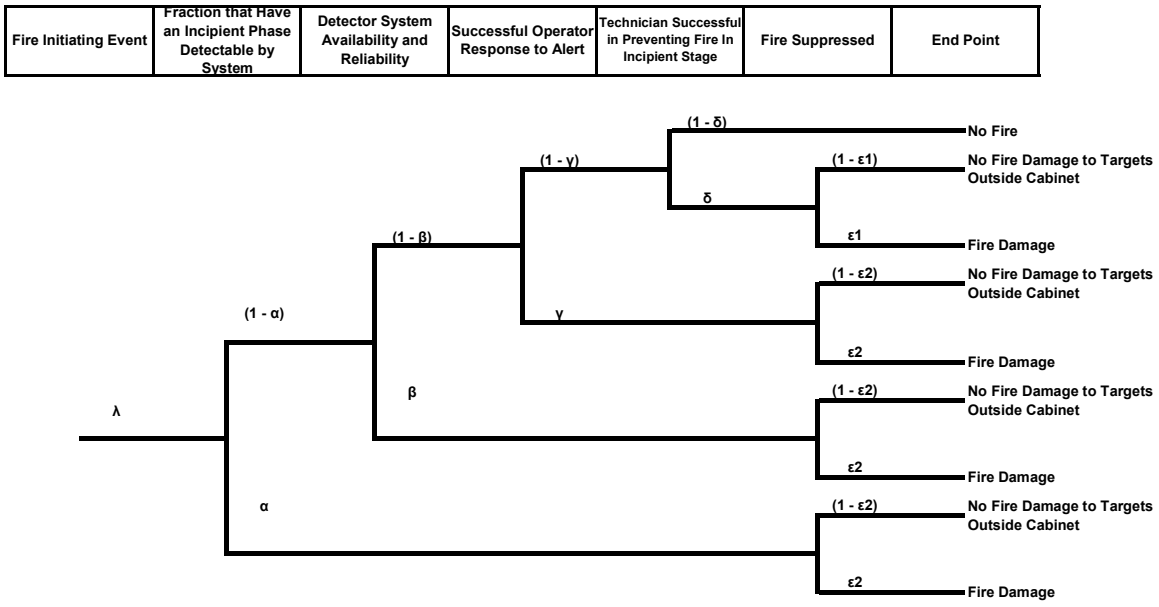
The first relates to the population of components that would exhibit incipient degradation. An additional factor should be added to the event tree to address the fact that a given electrical cabinet may have some percentage of components that may fail quickly and therefore not allow credit for incipient detection. Examples include electrical/electronic circuit boards that contain electrolytic capacitors, chart recorder drives, cooling fan motors, mechanical timers driven by electric motors, etc.

The second relates to the rate of component degradation. The failure mechanisms that provide indication in the incipient phase may occur over extended time periods. This time period has a direct correlation to the effectiveness of the process since a longer degradation time would imply that the time period between detection of the degrading condition and a transition to a flaming fire would be longer, resulting in a higher probability of success that a fire will be prevented or, if not prevented, mitigated. However, although there is significant operating experience with VEWFDS, there is limited useful data documenting the duration of the incipient degradation time. As a result of the limited data, there is uncertainty related to the incipient degradation time. This uncertainty should be factored into the assessment of VEWFDS effectiveness.

The third relates to the response to a VEWFDS alert/alarm. Since the proposed approach uses human intervention as the primary means of mitigating an impending fire, a factor should be inserted that allows this important part of the process to be accurately modeled.
In order to prevent a fire, the response activity must also include actions to remove power from the failing component/subcomponent. As the event tree is currently constructed in the EPRI report, the actions to respond to the location and find the component/subcomponent have been addressed (essentially the “Operator Response”). The skill set needed to accomplish this is similar to that for responding to any other fire: the skill set corresponding to that of an operator or trained fire brigade member. However, once the component/subcomponent has been located and identified, another skill set will be required. This task (call it the “Technician Response”) requires someone knowledgeable in electrical/electronic circuits that can locate and read the appropriate drawings to determine how to remove power from the degrading device. In many cases, this activity is not a trivial exercise. It may involve researching numerous drawings (elementary, connection, interconnection, etc.) to properly locate the appropriate fuse, circuit breaker or switch. In some cases, the required isolation device may not be in the same cabinet, row, or possibly even in the same room.

If the actions to locate the device and remove power are not taken at an early stage, the effectiveness of the incipient process to prevent a fire is reduced. Note that this factor can be influenced by the rate of component degradation. If the degradation process occurs over a long time period, and is detected early in the process, the available time to prevent/mitigate a potential fire is much greater, allowing a higher probability of success.

Based on these considerations the following event tree is proposed for more accurately assessing the risk of fire assuming that a VEWFDS is installed. There is limited data from which the various factors can be derived. The EPRI report has cited a small number of tests that demonstrate the sensitivity of VEWFDS. The tests, however, do not address the duration or probability of the incipient degradation process that is a key factor in the true benefit of these systems. The NRC approach to dealing with this lack of data is addressed in the following.



Discussion of Branches of NRC Event Tree:

At this time, this interim staff position, and the corresponding event tree, only applies to the installation of VEWFDS installed to monitor incipient fire conditions inside low voltage (less than or equal to 250V) electrical cabinets. The branch points of the event tree are discussed in turn below. Each branch includes conditions that should be in place to obtain the credit listed.

Fraction that Has an Incipient Phase Detectable by System: For VEWFDS monitoring equipment inside electrical cabinets with a voltage of 250V or less, α, the factor for that percentage of components that do not exhibit incipient degradation may be set to 0.

- To take credit for this value, only low voltage (less than or equal to 250V) electrical cabinets may be included. In order to set this number to 0, the analyst must verify that the cabinet does not contain fast acting components (such as electrical/electronic circuit boards that contain electrolytic capacitors, chart recorder drives, cooling fan motors, mechanical timers driven by electric motors, etc.) This

assumption should be confirmed by inspection of the cabinet and adjusted if necessary based on the results of the inspection if there are components that would be fast acting. If fast acting components are present, the event tree should include the branches addressing the Fraction that Has an Incipient Phase Detectable by System (α). For instance, if a cabinet contains 25 relays that would not be fast acting, along with a cooling fan and a motor-operated timer relay, the licensee could ratio the number of fast acting components (2) to the total number in the cabinet (27) and come up with a value for α (α = 2/27 = 0.074).

- Where aspirated VEWFDS systems are used, the characteristics of the cabinet to be monitored must allow the use of an aspirated VEWFDS (aspirated systems would not function properly in a tightly sealed cabinet).

- In addition, in contrast to the EPRI position, 480 V AC cabinets and rotating equipment are also excluded. If licensees desire to credit VEWFDS on components with fast acting, higher voltage systems or components, or rotating equipment, additional factors should be included to address their higher probability of not exhibiting incipient behavior.

Detection System Availability and Reliability: Success for this branch in the event tree means that the VEWFDS has issued an alert. β, the failure probability for this branch can be determined using the process provided by EPRI in 1016735 or set equal to 1E-02.

- The licensee should justify that their system is sufficiently similar to the systems evaluated in EPRI 101673 when using this value for reliability. For example, EPRI 101673 primarily has information on cloud chamber and laser aspirating detector systems. The use of other technologies should be justified to use the proposed value above.

- The system should be designed and installed by trained and qualified technicians to NFPA 76 following appropriate vendor guidance, tested in accordance with an appropriate standard including appropriate vendor requirements, and maintained in accordance with manufacturers and code requirements.

- The system should pass the full vendor's acceptance test, associated sensitivity testing, including any extended period of commissioning prior to being placed in service.

- In addition to the regular functional testing required by NFPA 76 and any required preventive maintenance required by the vendor, the system should be tested and maintained in accordance with NFPA 72 and all vendor requirements (calibrated as required by the manufacturer).

- Most VEWFDS have the capability to provide two or more alarm levels. Alarms that are set to occur prior to the flaming stage are typically referred to as "Alerts" and alarms that are set to occur when the device has entered the flaming or true fire stage are called "Alarms." VEWFDS alert and alarm levels should be controlled through the licensee's setpoint control program. Calibrations, such as re-baselining the alert and alarm levels that reduce the sensitivity of the system should be evaluated to assure that the early detection function of the system is not compromised. Reductions in sensitivity should be considered in the fire PRA as a reduction in the system's effectiveness.

- Testing and calibrations should be documented; Documentation should be maintained for the life of the plant.

Successful Operator Responses to Alert: Success of this event implies that plant personnel have identified the cabinet which contains the source of the alert and have staged appropriately trained personnel (qualified fire watch as is used for hot work or a "Flash Watch") at that location who are prepared to initiate fire suppression if an actual fire (e.g., open flaming) were to break out. γ reflects the likelihood that plant personnel fail to respond to an alert signal in a timely manner (i.e., prior to outbreak of open flaming within the source). γ, the probability of failure of the operator/fire brigade to respond to the alert and find the component can be determined based on a Human Reliability Analysis (HRA) or conservatively set to 1E-02 if the VEWFDS is addressable to multiple cabinets or 5E-03 if the VEWFDS is addressable to an individual cabinet. The lower value recognizes that the cabinet affected is known and does not require additional investigation by the responders to identify the affected cabinet.

- The recommended value assumes that the VEWFDS provides at least one hour of warning prior to the actual outbreak of an open flaming fire. This value is considered conservative for an annunciator response when there is nothing else going on – since the alert occurs prior to any damage, it can be assumed there is no fire and no transient at this time.

- This number assumes that the operator response procedure directs the area and/or cabinet (if the VEWFDS is addressable to individual cabinets) to be investigated upon an alert from the VEWFDS.

- This number assumes that procedures would be in place to require establishment upon the annunciation of an alert of a qualified continuous "Flash Watch" (similar to that used to monitor hot work) until the potential for fire has been removed or until there has been a formal, documented evaluation of the event. (Note: One acceptable means of meeting this qualification requirement is to provide training in accordance with the requirements in NFPA 1081, "Standard for Industrial Fire Brigade Member Professional Qualifications," Section 5.2.1 "Manual Fire Suppression")

- Effective methods must be established for locating the source of the incipient detection (portable VEWFDS, thermography, etc.) and the associated equipment must be dedicated for use, maintained in an operable condition, available on site at all times and appropriately staged to be rapidly accessed by first responders when needed.

- First responders are properly trained to respond to the incipient condition, identify the faulted cabinet, and suppress potential fires. Personnel using portable equipment to locate incipient degradation must be trained in its use, including on-the-job training such that they are familiar with the equipment, procedures for its use and any limitations and/or precautions required. Also, adequate procedures exist, and the response process has been included within the scope of the fire brigade training and periodic drill process.

Technician Successful in Preventing Fire in Incipient Stage: To simplify the analysis, δ, the factor for the probability of failure to remove power from the device once it has been located, is set to 1. This is done because of the difficulty in assessing the likelihood of successful prevention.

This approach is taking credit for the fire watch only, as a surrogate for prevention. To be

effective, the licensee must commit to procedures that require an appropriately trained fire watch in place until the problem has been resolved. Success in this approach is ultimately judged based on the ability to control the fire rather than suppress it. So long as the fire is prevented from growing significantly, the adverse consequences related to a large cabinet fire, and the associated fire growth due to secondary combustibles are prevented. This is conservative, since in reality there would not be a fire contribution at all if the fire was prevented. In the case of fire prevention, the only impact on plant operation would be the unavailability of the component(s) in the cabinet for the duration of the repair.

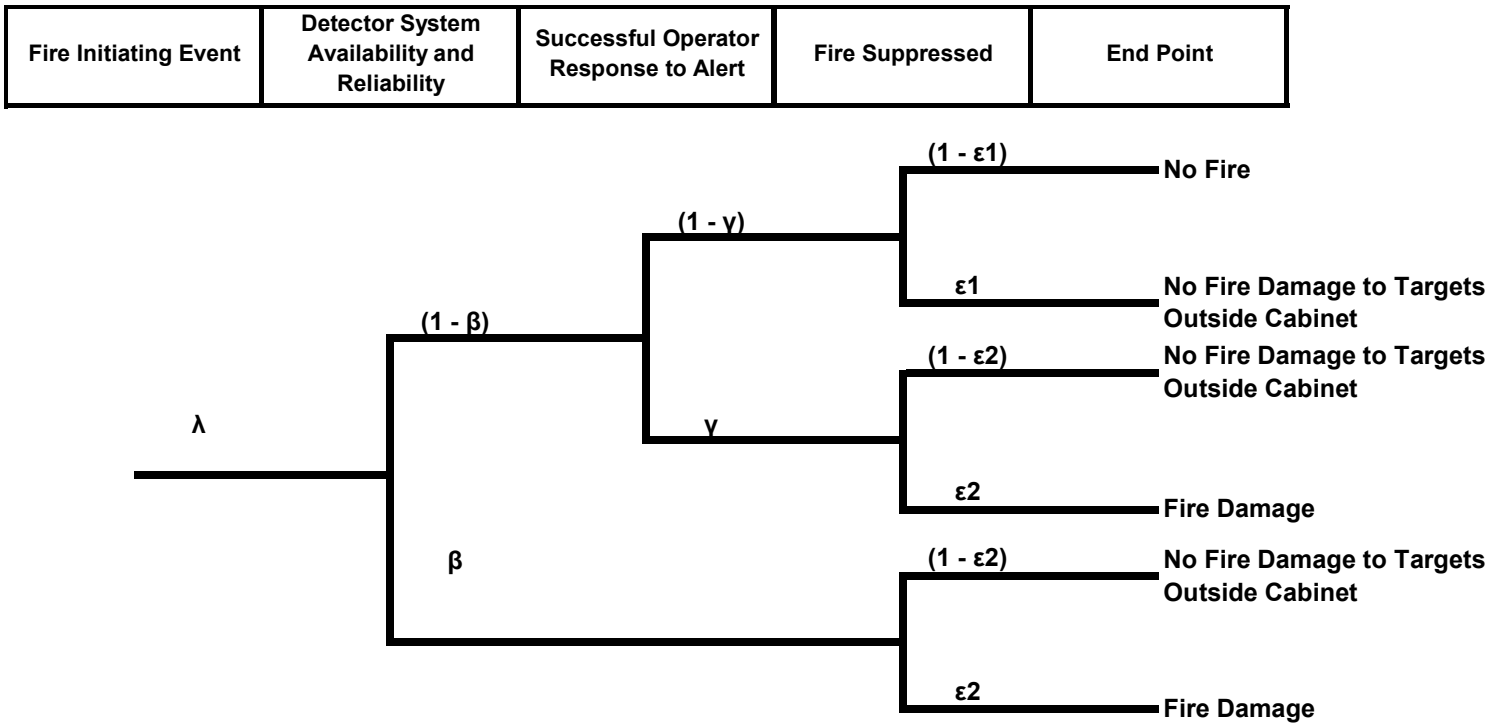
If a licensee desires to obtain more credit in this process, the more detailed NRC event tree may be used, including the branches with δ (with adequate and appropriate justification in the form of a detailed Human Reliability Analysis). One way a licensee could achieve significant fire prevention credit would be to "pre-locate" the isolation devices for all ignition sources within each cabinet in an effort to speed up the process. If such an effort was taken, additional credit for preventing fires could be allowed. This would need to include predetermining the isolation devices, conveniently displaying that information for use in response to VEWFDS alert, training responders so that they could rapidly locate and operate the isolation device(s), and drills to periodically demonstrate this ability.

Fire Suppressed: There are two cases for this branch point.

Success in the event following success in successful operator response to alert or alarm is that the "Flash Watch" stationed at the cabinet has successfully controlled the fire before it affects the target. ε_1 represents the probability that, given success of event γ, the personnel staged at the cabinet responsible for the VEWFDS alert fails to promptly suppress the fire (i.e., quickly enough to prevent damage to PRA targets outside the cabinet) once open flaming does break out. $\varepsilon 1$, the probability of "enhanced" non-suppression may be set to 1E-03. This is considered to be reasonable given the nature of the response required by a trained responder who is stationed at the location with the correct equipment.

Success for the branches following failure in the successful operator response or detector unavailability is prevention of damage to the targets by the fire brigade. $\varepsilon 2$, the probability of "normal" non-suppression should be taken from the Detection Suppression Event Tree in NUREG/CR-6850, Appendix P using the electrical fire suppression curve for manual suppression as appropriate. Credit should be given as described in Appendix P for automatic detection and suppression (normal spot detectors and automatic suppression in the area) as well as delayed manual detection, manual actuation of fixed suppression and manual suppression via the fire brigade.

With the above simplifications, the event tree simplifies to the following:



Other General Considerations

Note that the staff plans to document the licensee commitments associated with the VEWFDS design, installation, testing, compensatory measures and procedures for responding to the VEWFDS alert/alarms in each licensee's license amendment request and reviewed and approved in the associated NRC Safety Evaluation, as applicable.

Licensees that employ VEWFDS and model them in their Fire PRA models that do not use the proposed values provided in this position should justify the various split fractions used in the plant-specific application and provide a characterization of the uncertainty on each of the split fractions and perform a sensitivity analysis to demonstrate robustness of the proposed position on acceptability of the plant change. The licensee should describe the operator response in sufficient detail for the NRC staff to understand how the Human Error Probability (HEP) was determined. Regardless of how VEWFDS are modeled, licensees should provide a description of alarm response procedures, troubleshooting methods, and training of operators, maintenance personnel, fire watch standers, and fire brigade members.

Based on the possible significant risk reduction being credited for VEWFDS installation, licensees should include in their fire protection program appropriate compensatory measures to address the unavailability/inoperability of the VEWFDS. These compensatory measures should be controlled through the use of a licensee-controlled process such as a Technical Requirements Manual or other defined process used to address fire protection program impairments that will ensure that the compensatory measures will be carried out. For licensees that plan to install VEWFDS as part of the NFPA 805 transition, the process for defining and controlling the compensatory measures should be described in the NFPA 805 License

Amendment Request. Unless compensatory measures are evaluated to be equivalent to VEWFDS, such as continuous hot work type fire watch or use of a portable VEWFDS, an extended period of unavailability/inoperability may have a significant impact on overall plant fire risk. For example, an out of service period of four days would decrease the effectiveness of the system by an order of magnitude, based on the assumed availability factor. Even a day of unavailability would reduce effectiveness by a factor of about 3.

Two additional factors in a performance-based approach are the implementation of the NFPA 805 monitoring program and the fire PRA maintenance and update process. The staff expects licensees that implement VEWFDS to monitor the availability, reliability and effectiveness of the VEWFDS so that, over time, more accurate and representative data may be used in the risk model. As required by NFPA 805, licensees are expected to set availability, reliability and effectiveness targets and to take appropriate corrective actions when system performance does not meet the targets. Licensees are also expected to maintain their risk analysis current with the latest information. This includes consideration of new information from nuclear industry operating experience and external sources such as industry testing, research, data from other industries (such as the telecommunications industry), etc. While implementing the fire PRA maintenance and update process, if operating experience indicates that VEWFDS availability, reliability and effectiveness are not as high as currently modeled in the fire PRA, actions must be taken to update the analysis to reflect the new information.

Licensees are cautioned that while the installation of VEWFDS to monitor critical control cabinets may significantly decrease fire risk and positively impact several of the fire protection defense-in-depth attributes (preventing fires from occurring and rapidly detecting and suppressing those fires that do occur), consideration of defense-in-depth is a requirement of NFPA 805. Licensees are still required to demonstrate the ability to achieve the nuclear safety performance criteria assuming that a challenging fire impacts safe shutdown equipment. Depending upon the other defense-in-depth attributes for a given fire area, recovery actions and/or physical plant modifications may still be required to demonstrate the ability to meet the nuclear safety performance criteria.

Deviations from the information provided in this position should be justified and, prior to credit in NRC regulatory activities, should be submitted to the NRC for review and approval.

References:

1. Revision 0 to FAQ 08-0046, March 31, 2008, Accession No. ML081200120

2. NRC Draft Interim Position on FAQ 08-0046, Accession No. ML091750338

3. Resolution of stakeholder comments on the NRC Draft Interim Position, Accession No. ML093220197

4. EPRI 1016735, Fire PRA Methods Enhancements, December 2008, Accession No. ML090290195

5. NEI 04-02, Guidance for Implementing a Risk-Informed, Performance-Based Fire Protection Program Under 10 CFR 50.48(c), Revision 1, Accession No. ML052590476

6. NFPA 805, Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants, 2001 Edition (available through the Public Document Room or NFPA)

7. Regulatory Guide 1.205, Risk-Informed, Performance-Based Fire Protection for Existing Light-Water Nuclear Power Plants, Accession No. ML061100174

8. NRC Regulatory Information Summary 2007-19, Process for Communicating Clarifications of Staff Positions Provided in Regulatory Guide 1.205 Concerning Issues Identified During The Pilot Application of National Fire Protection Association Standard 805, Accession No. ML071590227

9. NUREG/CR-6850 (EPRI 1011989), EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities, Accession Nos. ML050940183 (Vol. 1) and ML050940189 (Vol. 2)